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UNMANNED COMBAT AERIAL VEHICLES:

EVOLUTION OR POTENTIAL REVOLUTION?

by

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Preface

In preparing for this paper, I examined quite a lot of material written on unmanned aerial vehicles (UAVs). Of all that I have read on the subject, the three most influential publications were: “UAV Technologies and Combat Operations, from the USAF Scientific Advisory Board, the Platform Panel report on UAVs I received from the Lockheed Martin Corporation, and Air Force Basic Doctrine, Air Force Doctrine Document 1, Sept 1997. I relied heavily on all three documents and I feel that they are mandatory reading for anybody professing interest in the subject.

I found that I used mostly my own experience with tactical fighters, operational test and evaluation and the USAF drone program. I appreciate the help I received from the USAF UAV Battle Lab at Eglin AFB and from Mr Paul Martin of the Lockheed Martin Skunk Works in California.

Abstract

This paper will deal with developmental and operational concepts of arming unmanned aerial vehicles. More specifically, I wished to explore the concept of developing an unmanned combat aerial vehicle (UCAV) that will provide the capability to greatly expand the potential of air power as an instrument of national policy. I had believed that an academic and educated discussion of this topic was still relatively new territory for the USAF. As I began to study and research the issues involved, I found that in fact there is a tremendous amount of material already written about UAVs and associated theories on how to best develop an armed capability. I also found that most of these writings were very similar in nature. Invariably the paper or article would spend the majority of its content examining the historical development of UAVs. Then the remaining portion of the paper would be spent on either a very broad theoretical justification of the future need for UAVs or a very technical and intricate conclusion detailing specific UAV systems.

I have tried to break free from that mold as I wrote this paper. The purpose of this paper is to offer a guide to help develop a coherent Air Force policy on a UAV capability. It is not meant to simply advocate a specific airframe or airframe design concept. It is meant to influence the reader on what I feel is the potential to dramatically affect the capabilities and nature of airpower.

I wrote this paper from what I feel is a unique perspective compared to pervious written works. I have been in tactical aviation for 20 years flying the F-4 and F-117 in operational missions. I also had the distinctly unique experience to work with the USAF's drone program for the past 4½ years involving the QF-106, QF-4 and the smaller BQM-34 and MQM-107.

I found it extremely difficult to focus the content of the paper and to not be distracted by exploring tangent subject areas away from the "big picture." In the course of this paper I will limit discussion to the broad perspective of arguments needed to develop a viable UCAV. I will only address issues at the non-classified level. That in turn will severely limit the depth and scope of many points and issues. I will also not explore any concepts involving cruise missiles and satellite operations. In many instances I found that these systems will have a natural crossover into UCAV operations, but they are outside the scope of this paper.

My ultimate aim is to present a valid and credible argument that UCAVs should be viewed as a potential capability and not as mission specific airframe replacement vehicles. All the bits and pieces of technology are now in place to develop a UCAV. My goal is to get that development going in the correct direction.

Chapter 1

Where We Stand

> *UAVs have significant potential to enhance the ability of the Air Force to project combat power in the air.*
>
> —USAF Scientific Advisory Board

The concept of using unmanned aerial vehicles (UAVs) as a warfighting capability is not new. There have been many examples of the successful use of UAVs throughout the history of air power. In recent years the UAV has come into it's own as a platform to perform intelligence, surveillance and reconnaissance (ISAR) in the Gulf War and the Bosnian conflict. While most activity seems centered on the reconnaissance role of the UAV, the concept of using UAVs to employ weapons is gradually beginning to formalize. There has been much written on the subject that offers many varied and often conflicting views on how best to develop and employ an unmanned combat aerial vehicle (UCAV).

This paper will explore the conceptual idea of developing a viable UCAV system for the USAF. A recent study by the USAF Scientific Advisory Board examined this issue of UAVs and combat operations in detail. Developing a UCAV system appears to be a controversial subject in the USAF flying community; however, the Scientific Advisory Board found that "UAV's have the potential to accomplish tasks that are now, for survivability or for other reasons, difficult for manned aircraft, including counterair.[1]"

The board concluded its report by stating "UAVs can be weaponized in the near term using an existing weapon (hypervelocity kinetic energy penetrators) with a family of warheads.[2]" This paper will explore those statements and offer suggestions on how best to develop a UCAV capability.

The primary advantage to developing a mature UAV capability will be the resulting leap in airpower capability, but to many the concept of weaponizing UAVs may seem to radical or too risky. There is a tremendous amount of resistance to the armed UAV concept amongst the rank and file pilot community saying that it can not be done, that we do not have the technology or that manned platforms can do the mission better.[3] The culture of the fighter and bomber pilot communities in the Air Force dictates a common attitude concerning UAVs. The feeling is that due to technological limitations, UAVs are a long way off from presenting, if ever, a practical warfighting capability outside the ISAR role. I know better!

During the summer of 1994, I flew in a very peculiar mission at Holloman AFB in New Mexico. I led a formation of four F-106s in a test mission against two threat aircraft flying on the White Sands Missile Range. The F-106s took off from runway 22 at Holloman at 70-second intervals and joined into a lead-trail formation of two elements. While we waited for the adversaries to enter the range we orbited in a race track pattern at 2000' above ground level (AGL) at 300 knots true airspeed (KTAS) to conserve fuel. When the adversaries arrived on the range and were ready, we dropped to 1000'AGL and accelerated to 480 KTAS. At the "Fights On" call, we departed our orbit to engage the adversaries in an element trail formation of exactly two miles with the wingmen in a precise formation 2000' off the respective leader's right wing and 1000' aft of his 3/9 line. As the adversaries turned hot to engage us we dropped to 500'AGL and accelerated to 540 KTAS maintaining the same lead/trail formation. At that altitude and speed the noise in the F-106 cockpit was deafening and the temperature in the 40-year-old jet quickly climbed to above 130 degrees.

We flew a total of four engagements. During each engagement we reacted to the threat aircraft with a series of low altitude 5 G maneuvers and extensions, employed chaff and various electronic countermeasures (ECM) to try to defeat their missile attacks. Following the four engagements, our flight was reformed into a loose fourship formation to complete a battle damage check, and then we began our recovery back to Holloman. Due to mission considerations, each F-106 split away from the formation in 10-minute intervals and flew a straight-in approach to runway 04.

For most fighter pilots it would have seemed a relatively common 4v2 tactical training mission. With the exception of the relatively low altitude environment, it would have been called—standard! What made this mission peculiar was that after I taxied my aircraft out to the runway, it took off, flew the entire mission and landed under the control of a remote operator located in the next county at the White Sands range control complex. I was not flying a F-106, but actually a QF-106 full-scale aerial target (FSAT) assigned to the 82d Aerial Targets Squadron (ATRS). The QF-106 is a modified F-106 that is used as a target for live fire missile test and evaluation. It incorporates an autopilot and remote control flight system that allows it to be flow unmanned in most of the flight envelopes of any modern high performance fighter. It has the capability to fly precise high G, low altitude and formation maneuvers. It can employ chaff, flares, ECM and various other expendables on command by the controller or in a pre-programmed mode.

While we were flying a dry run weapons test data mission, the engagements were not scripted. The QF-106 controllers reacted to what the adversaries were doing based on calls from the ground control intercept (GCI) controllers. The ONLY combat capability the QF-106s lacked that day was offensive firepower!

Another example to be examined is the F-117A Stealth Fighter. The F-117 is a superbly designed weapons platform. It uses a combination of reduced flight signature (stealth) and precision guided weapons to dramatically affect concepts of weapons employment and airpower. In the F-117, the single pilot flies a pre-determined route striking one or two pre-planned targets. With a precision internal navigation system (INS) the aircraft has the capability to fly the route entirely on autopilot even to the point of making precise timing adjustments to the time of predicted weapon impact. The pilot makes all the decisions and control inputs for sensor operation, target acquisition, weapons release and terminal guidance. Naturally he can override the autopilot and take manual control when needed. However, it is commonly joked about that all a F-117 pilot is paid to do is raise and lower the landing gear, perform aerial refueling and handle in-flight emergencies. If a system were installed to down link sensor and weapons images to a manned ground station, and a signal were provided to up link command control of the sensor and weapons release and guidance—the joking touches very close to reality!

I am in no way advocating modifying retired or active fighters and using them as unmanned combat aircraft. On the contrary, I believe that using retired fighters as unmanned vehicles for **any** use besides developmental test and evaluation targets is foolhardy. However, I do feel that the QF-106 mission and F-117 capabilities demonstrate that the technology necessary to develop a true armed UAV capability does now exist.

ATTRIBUTE	FUNCTIONAL IMPACT
ENDURANCE/ PRESENCE	• Persistent Surveillance • Continuous Deterrence • Reduced Aircraft-per-Orbit Quantities required • Reduced crew Fatigue • Board, Distributed Communications relay • Self-Deployable From CONUS; Can Operate from CONUS • Reduced cost of coverage
UNMANNED	• Perform High Attrition Combat tasks • Carry Weapons With Possible Fratricide Possibilities • Operate in Contaminated Environments • Operate in Provocative Role, Drawing Fire • Potentially Simpler; Reduced Cost • Reduced Crew Fatigue Problem • Reduced Cost of Coverage • Greater Need For Command and Control Tether
AUTOMATED	• Simpler, Less Costly Training • No Crew Safety testing • Control Interface Simpler • Less Stressing to Crews • Reduced Physical requirements for Operators
DISTRIBUTED AND PROLIFERATED	• Quick response Within Zone of Coverage • Behind-the-Lines Operation • Combined Attack (Multiple Weapons) • Broad Area Coverage With Multiple Sensors • Persistent Surveillance • Reduced System Vulnerability
HIGH ALTITUDE OPERATION	• Survivable • Performance Enhancements • Broad Area Coverage • Reduced Cost of Coverage • Advantageous Geometry For Data Link Intercept
LOW ALTITUDE OPERATION	• Loss Affordable • Operate at Short Range (Smaller Weapons, Jammers, Radars)

Table 1 ATTRIBUTES OF UAVS[4]

The table above demonstrates an insightful and methodical examination of UCAV potential. The list (provided by the USAF Scientific Advisory Board) does representative a good summation, but it is by no means all inclusive. The most common arguments for a UCAV include the ability for saving lives, reducing cost and improving performance.[5] A true UCAV will have the attributes such as extreme endurance and the ability for precision attacks against any target without the risk of endangering a pilot. [6]

However, the true advantage to a UCAV will not be in saving pilot's lives or reducing airframe cost. The basic notion of endurance and persistence of airpower in a high threat area will offer an explosive increase in capability to regional commanders and the national command authority. When that capability is developed without the consideration of endangering flight crews (as with conventional manned aircraft) airpower will then provide truly revolutionary options to military and national leaders. That revolution will augment existing manned weapons systems and will allow the Air Force to effectively and efficiently respond to a situation at any level of political or combat intensity in a conflict for the first time in it's history.

Notes

[1] Worch, P., Report on UAV Technologies and combat operations (Vol I), Dr peter Worch, United States Air Force Scientific Advisory Board, Washington DC, Nov 1996, p. vii.

[2] Worch, P., Report on UAV Technologies and combat operations (Vol I), Dr peter Worch, United States Air Force Scientific Advisory Board, Washington DC, Nov 1996, p. vii.

[3] This is the opinion of the author and is not substantiated by any data or by any other means

[4] Worch, P., Report on UAV Technologies and combat operations (Vol I), Dr peter Worch, United States Air Force Scientific Advisory Board, Washington DC, Nov 1996, p. 13

[5] Nolan, Robert C, The Pilotless Air Force? A look at Replacing Human Operators With Advanced Technology, Major Robert C Nolan, USAF Air Command and Staff College, Maxwell AFB, Al, March 1997. P. 9

Notes

Chapter 2

Historical Development of UAVs

Aerial torpedoes which are really airplanes kept on their course by gyroscopic instruments and wireless telegraphy, with no pilots on board, can be directed for over a hundred miles in a sufficiently accurate way to hit great cities. So that in the future, the mere threat of bombing a town by an air force will cause it to be evacuated, and all work in munitions and supply factories to be stopped.

—General Billy Mitchell, 1924

The "aerial torpedoes" described above by Gen Mitchell may not seem to fit into the generally accepted concept of a UAV. It may appear that he was talking about cruise missiles, but in fact it IS an example of an unmanned aerial vehicle. The idea of using unmanned vehicles should not seem so very foreign when one looks at the concept of many modern weapons. An air-to-air radar homing missile, the GBU-15 and AGM-130 family of command guided bombs and cruise missiles are all examples of unmanned aerial vehicles.

The majority of recent unmanned development has been limited to an ISAR capability. During the Cold War of the 1950s, the USAF relied on manned reconnaissance on the boarder and into the former USSR. The risk of manned overflights of the Soviet Union was demonstrated in 1960 with the shoot down of an American U-2 high altitude spy plane. Soon after the incident with the U-2, the BQM-34 subscale target drone was developed and fitted to existing photographic reconnaissance cameras. Still later, a modified BQM-34, designed to fly at high altitude and with specially fitted cameras, became the first UAV designed specifically for reconnaissance mission.[1] Designated the Ryan 147B (AQM-34Q), this aircraft was used for many years over Cuba and later extensively in Vietnam. [2]

There have been several demonstration programs developing the unmanned vehicle in various combat roles to include flak suppression, chaff dispensing, target designation and weapons delivery. The AQM-34 demonstrated dropping 500lb unguided bombs, the Stubby-Homing Bomb (HOBO) and launching the electro-optically (EO) guided AGM-65 maverick.[3] The missions were always under test conditions, and never an operational success. During the resulting military draw down following the end of the Vietnam war, all interest in weapon carrying UAVs seemed to disappear. Interest in UAVs was then centered on target applications for live fire missile test and evaluations.
During the late 1980's Air Force interest in UAVs was rekindled with the eventual development of the Tier II (Predator), Tier II plus (Global Hawk), and Tier III (Dark Star) reconnaissance-surveillance programs. Suddenly, interest increased with the promise of a new generation of UAVs boasting automated flight, long endurance, and "modest" cost when compared to manned reconnaissance aircraft .[4]

Air Vehicle Data		*Payload*	*Status*
Tier 2 Predator **($3.2M)** 	Gross Wt (lb) - 2,000 Altitude (ft) - 25,000 Endurance (hr) - 50+ Payload (lb) - 450 Wingspan (ft) - 49 Airspeed (kts) - 60	SAR - 3 m, 0.3 m EO/IR - NIIRS 6.5 Ku, UHF SATCOM CDL, UHF LOS Comm	Operational
Tier 2+ Global Hawk **($10M)** 	Gross Wt (lb) - 24,000 Altitude (ft) - 65,000 Endurance (hr) - 42 Payload (lb) - 2,000 Wingspan (ft) - 116 Airspeed (kts) - 300	SAR - 3 m, 0.3 m to 200 km EO/IR - NIIRS 6.5/5/5 Ku, UHF SATCOM CDL, UHF LOS Comm	In Build
Tier 3- DarkStar **($10M)** 	Gross Wt (lb) - 8,600 Altitude (ft) - 45,000 Endurance (hr) - >8 Payload (lb) - 1,000 Wingspan (ft) - 69 Airspeed (kts) - 350	SAR - 3 m, 0.3 m EO/IR - NIIRS 6 Ku, UHF SATCOM CDL, UHF LOS Comm	In Test (#1 Crashed)

Figure 1 EXISTING UAV PLATFORMS[5]

Even as UAVs demonstrated a tremendous capability during the Gulf War, the current field of unmanned vehicles has been hampered by controversy and poor operational performance. Seemingly frequent UAV crashes have marred many programs reducing confidence and adversely affecting developmental and operational budgets. Many UAVs have crashed on take off and landing perhaps due to the removing of the pilot from the aircraft without providing sufficient situational awareness and “seat of the pants” feeling to perform the piloting operation. Other unmanned vehicles were successful in flight, but achieved disfavor for reasons of program cost growth or system performance limitations.[6]

To advance an unmanned capability beyond the already credible ISAR capability, the present day UAVs must be used as a building block. Technology will play a crucial role in developing any UCAV capability.

Technology	*Past*	*Present*	*Future*
Affordability	Marginal	Design to Cost Implemented	Low Life Cycle Cost Realized
Data Links	Analog/Low Bandwidth	Digital, High Cost for Bandwidth	Standardized for USAF Architecture, Modular, Affordable
Engines	Whatever Available	Off-the-Shelf Commercial	Designed for UAVs, More Fuel Efficient
Human Systems	Automate What Was Technically Feasible; Human Filed the Gaps	Inconsistent Function Allocation; Minimum Attention to Human Factors	Simulation-based Design for Systems Relevant to Human
Low Observables	None	Current Technology: Some Penalties Perceived Costly	Lower Penalties, Lower Signatures, Lower Cost
Mission Planning	Little Automation	Some Automation, Slow, Inflexible	Automated, Flexible, Fast, Utilizing Parallel Computers
Onboard Processors	Limited Capability	Good Capability at Reasonable Cost	Excellent Performance/Low Cost
Producibility	Not Emphasized	Major Advances, Low Cost Tools for Composites	Designed for Low Rate, Low Cost Production
Sensors	Heavy, Bulky, Marginal Reliability	Major Improvements	Modular, Lightweight, UAV-Tailored
System Design Integration	Modified Manned Aircraft Techniques	Design Automation System Simulation	Integrated Design/ Simulation/ Manufacturing Automation
System Reliability	Marginal	Better, but not Acceptable	Robust Systems, Very Low Failure Rate
Training	Reliance on Prior Experience and OJT	Delegated to Contractors; Military Training Evolving	Crew Selected and Trained Using Modern Methods
Vehicle Management Systems	Off-the-Shelf, No Integration, No Automation	Some Integration, Rudimentary Automation	Optimized for UAVs: Performance, Weight, Cost, Automation
Vehicle Structure	Manned A/C Metal Approach, Large Parts Counts	Composites Not Fully Exploited, Reduced Part Count	Tailored Composite Structure, Very Low Part Count, High Fuel Fraction
Weapons	None	Little Consideration	Small, Modular, Integrated System Design

Figure 2 LEAD IN TECHNOLOGY[7]

It should be noted that all the critical technologies are already in place to begin conceptual development of a viable UCAV. The need for the Air Force is the determination to proceed, and to proceed in the correct direction to capitalize on the potential UCAVs offer.

Notes

[1] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[2] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[3] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[4] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[5] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[6] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

[7] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p. 1-1.

Chapter 3

UAV General Capabilities

UAVs have several basic advantages over unmanned systems including long endurance and no risk to crews. (In situations) Where these attributes are key, UAVs will be the platform of choice.

—Air Force Issues Book, 1997

What exactly does the term UAV mean? *Unmanned* aerial vehicle implies an automated "hands off" operation in which the aircraft, under near total computer control, completes the mission with limited or no human interference. That should not be the case in developing UAVs. The term u*ninhabited* aerial vehicle is not meant to be a politically correct gender neutral term. It implies that a man is in fact "in the loop" making control inputs and **ALL** tactical decisions. Adding the natural extension of a combat capability (i.e.; the direct ability to shoot things) and UAV becomes a UCAV- uninhabited combat aerial vehicle. A true UCAV in this context is differentiated from the "aerial torpedoes" by means of a multiple use capability and the capability of employing weapons against multiple targets in a dynamic tactical environment.

The Report on UAV Technologies and Combat Operations, published in 1996, very correctly describes what should be the USAF UCAV philosophy. "In order to fully exploit the potential of UAVs, the Air Force must think of them as new and complete systems with new combinations of advantages and disadvantages, rather than as vehicles with a single outstanding characteristic or as a slight variant of an existing platform.[1]" It is this "breakthrough" in thinking that is now the major obstacle in developing a viable UCAV platform.

This paper does not advocate any specific technical or performance UCAV attributes. I am less concerned with total endurance and payload capability than with a UCAV's ability to augment the USAF's capability to influence the **effects** of military action and hence political outcomes and conflict resolution. The effects of military action is **the** key point to the concept of UCAVs and must always be kept the overriding priority in UCAV development and design.

UCAVs should not be looked at as a panacea to solving tactical problems. They should also not be viewed as a replacement to manned aircraft, but must rather be viewed as a capability to augment them. The sole purpose of UCAV development should be to increase air power capability or mission coverage.   UCAVs should then represent an effective force multiplier--NOT simply as a way to save pilot's lives or as a cheap airframe alternative. I do not believe that a fully developed UCAV airframe will be "cheap" when compared to the current inventory of tactical weapons delivery aircraft. However, the capability they represent will be extremely cost effective when compared to the alternative of sending a package of manned aircraft with all the required support assets.

To achieve the full potential of these systems, UCAVs should be developed with the goal of solving three traditional weaknesses of conventional airpower. Each of these weaknesses or environments, may seem brutally obvious, but each should be examined in the context of UCAV development. Any successful UCAV system must naturally exploit one or all of these environments. To possess a capability to operate with impunity in these environments is also the sole basis for an argument in developing a UCAV system. To operate without regard to these environments totally negates the requirement of a UCAV—the mission can then be done just as well with a conventional manned aircraft without the need for a UCAV system.

#1 High Threat

Besides mission degradation and a resulting lower probability of mission success, the most obvious factor in operating in a high threat arena with manned aircraft is the high potential for losing both the pilot and the airframe. UCAVs specifically designed to operate in high threat environments will be able to accomplish the mission with a lower probability of losing the airframe. Keeping a pilot out of harm's way is self-evident. In simple terms of economics the resulting mission impact of losing a UCAV will be far less than a costly fighter or advanced manned bomber that is sent into harm's way.

However, by far the most profound impact will be the change in planning concepts. The risk assessment by the National Command Authority or theater Commander of employing a high value manned asset against a high risk objective may dramatically reduce the US's resolve or even capability in affecting a military outcome. This is especially true in a politically charged environment or in a situation of limited mission objectives in the threat area.

In 1968, USAF Major John C Wright was tasked to lead a flight of 12 F-105s flying out of Osan, Korea. His mission had the highest priority with tasking coming directly from the White House. His target was the intelligence-gathering ship, the USS Pueblo, which had just been hijacked by the North Koreans and was then docked at

Wonson Harbor on the east coast of the peninsula. Major Wright was briefed that due to the vast threat array of Mig aircraft and surface to air defenses in North Korea and around Wonson, few if any of the 12 F-105s would survive the mission.[2]

Maj Wright assured his superiors that he would of course attempt the mission if he were so ordered, but the air-to-air and air-to-ground threats were academic to his survival.[2] During the height of the Viet Nam conflict, there were no KC-135 tankers available in Korea to support this time critical mission, and the F-105 did not have enough fuel to make it back to friendly territory following the strike. After Major Wright and his flight sat a tense day of cockpit alert, the mission was cancelled by President Johnson[3]. It was obviously felt that a one way suicide mission to sink the Pueblo was not in the best interests of the United States. The North Koreans were free to collect and disseminate the captured intelligence data and equipment: an incalculable loss to this country!

Having a fully capable (thereby expendable) UCAV available will provide a tremendous capability to commanders that will eclipse the individual airframe cost and operational loss potential. Employment and strike considerations will then be based on strategic and political implications and not on tactical risk assessment. The leverage given to national decision makers will then enter a new era of potential military operations and their impact. Missions will no longer have to pass the threshold of risking manned aircraft to justify the application of airpower. Airpower can then be applied across the spectrum of conflict and planned directly to achieve a desired outcome or effect while disregarding mission risk.

#2 Endurance

There are two issues to identify in the environment of endurance. The first is the most obvious--that of economics. The longer the endurance, the fewer aircraft are needed for coverage over the target area. Fewer aircraft needed in a target area translates to fewer aircraft required and fewer procured. The second issue of endurance is the most relevant. Endurance is an environment that should not be thought of in the number of nautical miles an aircraft can fly, or even how long it can stay airborne. In a UCAV context, endurance is translated to actual time available over the target area. Time spent transiting to and from the target area is non-consequential and must be factored out. Endurance then equates to persistence in mission coverage.

Persistence in air operations is a basic tenant of airpower that will be enhanced by a UCAV capability. However, true persistence in a UCAV will now also allow airpower to potentially service the requirement of national "presence" on a battlefield or politically sensitive area. What makes the concept of using a UCAV to project national presence in a situation important is the ability to do so while bypassing the "boots on the ground" mentality. American troops would no longer be required to be placed in harm's way in the area of conflict to project American resolve or influence. An orbiting UCAV would provide force projection and on call employment options to the theater commander without the risk of friendly losses.

Following the hostilities in the Gulf War, the regime in Iraq has recently adapted a confrontational stance towards the United Nations. By denying UN weapons inspectors access to key facilities, they were in violation of UN directed mandates. Previous tensions had resulted in some limited airstrikes with little or no long term affect. In a recent lecture to the USAF Air War College, a noted airpower theorist was asked how he would militarily respond to the recent tensions in Iraq. His answer was that "we need to show our presence and determination to the Iraqis. Maybe we should develop some type of persistent sky writing and write a message over Baghdad."[3] While "persistent skywriting" may or may not be very intimating to the regime, a high endurance UCAV parked over the city would be. That capability would allow national decision makers the option of deploying a credible and appropriate military presence for an extended period of time.

Endurance would normally imply a high altitude flight envelope as in the case of the Tier II. However, operating altitude should be a design and performance compromise of weapon capability, survivability and endurance.[4] Advances in technology may allow a higher operating altitude for highly precise weapons. More dynamic targeting problems may require a lower altitude to enhance maneuvering capability. However, a vehicle need not orbit and then employ weapons from the same altitude regime. UCAV design may necessitate an aircraft to orbit at higher fuel conserving altitudes and descend to lower attack altitudes. There are many variables, but it must be remembered that endurance, as it applies to UCAVs, must be dealt with in terms of time spent in the target area.

#3 Political Sensitivities to Captured Pilots

This environment was indirectly addressed on the issues of high threat operations. It poses a similar problem, but the argument intensifies when the outcome of having a manned aircraft shot down over enemy territory is looked at. When an aircraft is shot down in the target area, one of three things will happen—either the pilot is killed, rescued or is captured. If he is killed, it is a tremendous loss to his family, his unit and the country. However, from a strategic perspective, unless such losses prove to be prohibitive it numbers, the conflict will move on as before with little or no change to the desired outcome.

If a pilot is shot down, the USAF will expend tremendous resources in an effort to recover him. It would be beneficial to examine the problem in the cold light of logic and explore the balance of benefits to costs in any recovery attempt. However, it is impossible to evaluate combat rescue with harsh logic and there will always be attempts made to recover downed combat pilots. To simply maintain a capability to provide combat rescue services is a substantial investment in resources and people by the USAF. Any rescue attempt behind enemy lines will be costly in terms of resources and also potentially catastrophic for the personnel involved. Naturally, if an unmanned vehicle were lost on a mission, there would be no requirement to rescue a pilot. But simply reducing risk by mitigating the need for a rescue mission is not the issue. The issue as related to UCAVs is how the consequence of a friendly shoot down or a failed rescue will affect decision making during mission planning.

If the pilot is captured, his war is not over. From a humanitarian perspective, any chance at limiting the potential for American service members to be put at risk of becoming the prisoner of a hostile regime should be investigated. But there is a broader perspective to look at regarding a captured pilot. There are many scenarios that a captured American pilot will have immense political ramifications to the conflict. The incident mentioned earlier in which an American U-2 spy plane that was shot down over the Soviet Union in May of 1960 makes a good example. The pilot of that plane, Francis Gary Powers, came to have a tremendous effect on US-Soviet relations and American policy towards the Soviets. Due to political ramifications, his capture provided the Soviets a tremendous tool to be used to strengthen their claims of American aggression that went well beyond the implications of single U-2 mission.

In an unlikely scenario, imagine the Iraqi policy of confrontation with the US continues as does its interference with UN weapons inspectors. The UN decides on military force to pressure Iraq to comply with UN mandates. Air strikes are carefully planned to surgically attack Saddam Hussein's leadership, infrastructure, oil production and transportation facilities as well as various Republican Guard units. The missions go very well—all targets are successfully serviced (destroyed) and all but one aircraft returns to friendly bases. Now imagine the leverage that Saddam Hussein would enjoy if he were to have a captured pilot to parade in front of the cameras for the western media. The national objectives in this conflict will then immediately be effected. All public attention will shift towards the fate of this one pilot. His capture will now have a much more direct effect on United States political capabilities and objectives than a single manned strike sortie would warrant.

There are many seemingly valid arguments for and against the development of a viable UCAV. When the UCAV is viewed as a system to replace existing manned aircraft, unmanned aircraft will present only limited potential with associated arguments against their development. To fully exploit their true potential, UCAVs must be viewed in terms of operating in the three environments: high threat, endurance and political sensitivities to captured pilots. If a UCAV platform cannot offer a solution to at least one of these environments, then I predict it will not survive the turmoil of design, development and budgetary scrutiny. If a UCAV can perform its mission under these environments it will naturally be developed as a manned aircraft force multiplier that will have the potential to dramatically affect the capability of airpower.

Notes

[1] Worch, P, Report on UAV technologies and combat operations (vol), Dr Peter Worch, United States Air Force Scientific Advisory Board, Washington DC, Nov 1996, p. vii.

[2] Briefing and personal conversation with Col John C. Wright (USAF retired) at Randolph AFB, TX, 19 Jan, 1998.

[2] Briefing and personal conversation with Col John C. Wright (USAF retired) at Randolph AFB, TX, 19 Jan, 1998.

[3] Briefing and personal conversation with Col John C. Wright (USAF retired) at Randolph AFB, TX, 19 Jan, 1998.

[3] Briefing to the USAF Air War College, Maxwell AFB, AL, 24 Nov, 1997.

[4] Martin, Paul, Personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Skunk Works, Palmdale, CA, Nov 96, p. 24.

Chapter 4

UCAV Requirements

Removing the pilot from harms way is invariably the first priority in the present world of potent defenses and strong political sensitivities. The problem is functions of the pilot must still be performed, and the UAV will remain largely a concept until they can be done extremely reliably

—Paul W. Martin
Vice President, Tactical Aircraft
Lockheed-Martin Skunk Works

A UCAV system may take any one of many design paths. Several notional plans have been developed by the Lockheed-Martin Advanced Development Company. One proposed design concept has inlets and nozzles on the bottom of the vehicle together with the internal weapons bay doors. The vehicle would cruise or loiter in an inverted mode to present a low signature to ground radar and then conduct the low level penetration with weapons release from the bottom. It would be desirable to have conformal weapons to permit larger weapons loads.[1]

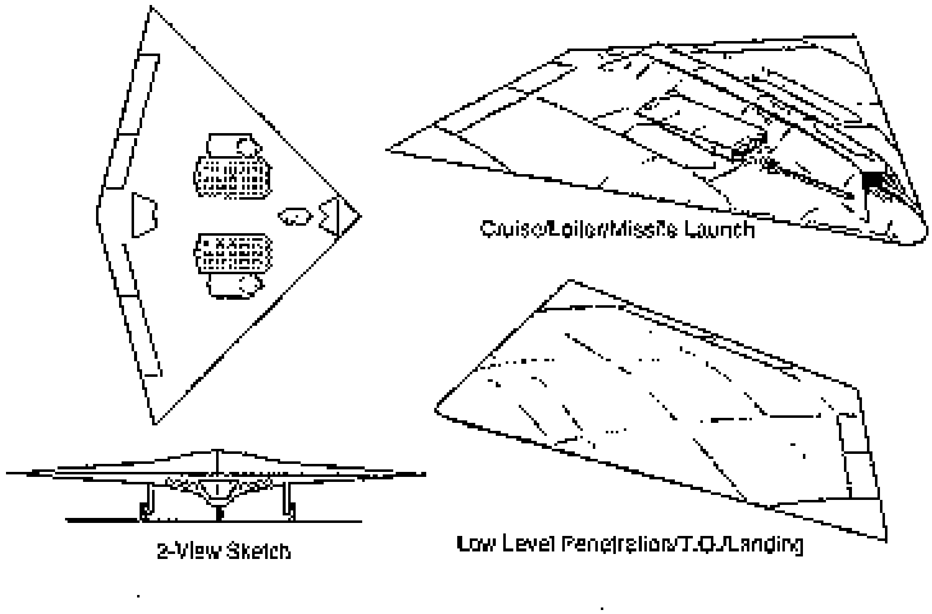

Figure 3 NOTIONAL UCAV[2]

While there are several UCAV design concepts being developed, it is important to understand that the aircraft design must be based on required mission characteristics. There are five basic characteristics that should dictate UCAV airframe design. They are crucial as compliance with these characteristics will dictate overall airframe engineering design and hence define UCAV capability. At this early stage in the UCAV developmental life, it is critical for the USAF to accurately define UCAV requirements. Industry (reference the notional concepts by Lockheed-Martin) must have a solid road map to effectively mate realistic design potential with anticipated manufacturing capability. The requirements that I see as mandatory in a UCAV are listed below.

#1 Stealth

A stealthy airframe is mandatory in a UCAV. Stealth connotes a reduction in the radar, thermal and optical signature of an aircraft. If a UCAV is not stealthy, it must then be employed under the umbrella of a traditional support package of suppression of enemy air defenses (SEAD), jamming, and escorting counter-air aircraft. The concept of providing manned escort aircraft for a UCAV into or while operating in a target area is contrary to any advantage of removing a pilot from a UCAV in the first place. The UCAV need not be stealthy in all scenarios all the time, but stealth must be designed into the aircraft as a counter to the high threat environment. If the UCAV system is not able to effectively operate unescorted in a high threat environment any argument to invest in a UCAV capability loses credibility.

Unfortunately, the stealth requirement of the UCAV also invalidates use of an "old" fighter that has been modified to operate under remote control. While the technology exists to modify an existing fighter for unmanned weapons employment, such a vehicle would offer no real advantage to traditional manned combat aircraft. A QF-106 (or it's replacement the QF-4) is certainly a very capable test asset. However, it could be weaponized only after great cost and effort and would be an extremely vulnerable target in a combat situation. Any combat mission with this aircraft would have to be escorted with conventional manned aircraft to suppress enemy defenses. The very notion of having to escort any unmanned aircraft, invalidates the entire concept of developing a UCAV capability. With very few exceptions, survivability in the high threat environment alone will generally negate any argument of modifying manned aircraft. It certainly will for any retired fighters like the QF-4.

To develop a true UCAV system requires a new airframe design to capitalize on stealthy signatures. A UCAV stealth capability should not be designed strictly along traditional F-117 and B-2 engineering solutions alone. "A UCAV doesn't have to be big, black and bat-shaped to be stealthy.[3]" Stealth implies optimizing all design features to capitalize on the stealthy signatures for the specified operating envelope and can be specifically tailored to a pilotless aircraft. A good example is the Lockheed-Martin notional concept of loitering upside down to present ground radars with the aircraft's stealthy top side.[4]

New technologies will invariable play a crucial role in a UCAV design and will be most prominent in solving the stealth requirement. A UCAV will not be limited to only the traditional concepts of airframe shaping and radar absorbent materials (RAM) covering to reduce radio frequency (RF) signatures. Size, flight characteristics and many classified radar, and electronic technologies will play a dramatic role in designing stealth into any UCAV. However, any UCAV concept not centered on a stealthy operating capability in the target area should be discounted.

#2 Reliable and Rugged

This characteristic may seem overly simplistic but it is not and it bears examination. A UCAV must work correctly the first time and every time. An accidental loss rate has been the single biggest contributor to the historic failure of UAVs to find their place in the force mix. Flight management systems (including) on-board flight control, communication links and ground station support are the primary contributors to this shortfall.[5]

Reliability must be built into the UCAV from the conceptual design to the manufacturing process and operational maintenance practices. A key factor to reliability will be the elimination of any "single point failure" modes. Any system critical to flight must have multiple back-ups built in. A second key factor in reliability will be component-mean-time-between-failure (MTBF) modes. If a UCAV is comprised of 100 sub-systems each with a 100 hour MTBF, the average MTBF of the total UCAV system will be one hour. That will result in a non-viable system.

Accident rates of the Predator reconnaissance UAV demonstrate the perceived intolerance of UCAV accidental losses. When deployed to Bosnia for combat support operations, the Predator UAV system flew approximately 350 operational sorties and generally operated with no more than 3 aircraft in theater. During those missions, the Predator suffered only 4 losses—three were due to mechanical failures and one was a hostile shootdown[6]. Based on the total operational hours flown, the ratio of flight hours to losses were 1/1200. Not a bad track record for combat operations for a UAV, yet the predator gained a reputation for being an unreliable system! It must be stressed that a UCAV will operate without the ultimate back up for flight control failures, aircraft/weapon systems malfunctions, and mission contingencies—a human being! A mean-time-between-accidental-loss of greater than 20,000 hours is necessary to keep the loss-related cost per flight hour below $500 for a $10 million UCAV so that the vehicle might have a total operating cost of $2000/flight hour.[6]

The characteristic of reliability will again invalidate the notion of modifying a retired manned airframe for use as a UCAV. The experiences of the USAF QF-106 FSAT drone aptly demonstrates the reliability potential of a UCAV F-4 of F-16. In 535 unmanned QF-106 launches, there were a total of 21 operational (Ops) mishaps.[7] In a combat role, these losses may not appear alarming, but an Ops mishap, or Ops loss, in this context, is the loss of an aircraft due to some other reason than a missile impact or as the direct result of a test requirement. Of all 21 losses, 76 percent were due to logistical problems, 14 percent were due to operational factors with 10 percent all other causes[8]. Of the logistics causes, 45 percent were due to failures of the basic aircraft systems and 40 percent were due to failures of the drone autopilot and control system (other causes were attributed to the remaining 15 percent).[9] These numbers demonstrate that a manned fighter modified for unmanned operations in a high failure item! It must be remembered that when attempting to fly a UCAV F-4, (depending on the tail number) you will be launching a 30-year-old airplane. That translates to 30-year-old hydraulic, electrical, flight control, pneumatic, and to some degree portions of the auto pilot and control systems.

The ruggedness of a UCAV must be addressed for it's entire flight envelope. Rugged does not mean a capability to sustain 20Gs. In a UCAV, ruggedness translates to a resistance to battle damages and the stresses of launch and recovery. The capability to absorb battle damage without having a pilot on board to take corrective action to mitigate system loss is obvious. I believe that the most stress put on a UCAV during its mission will be the launch and recovery. This is again demonstrated by the QF-106 program. Of all 21 operational losses, a total of 14 (or 66 percent) were in the landing and take off mode.[10] A viable UCAV system must be designed for a highly reliable and non-destructive launch and recovery capability.

#3 Performance

The elimination of a manned pilot/crew offers profound changes of vehicle design possibilities. Among those changes is a new look on aircraft performance requirements. Generally UCAV airframe performance centers on, but is not limited to, endurance. Endurance is one of the critical UCAV environments. Endurance in a UCAV is persistence. Persistence, as a basic tenant of airpower is crucial to an air campaign. Persistence allows more complete coverage of an assigned target area with an economy of force. Endurance over the target will allow the UCAV to service a wide range of "boring" missions bypassing the inefficient use of manned systems. This characteristic addresses providing full mission coverage without depleting manned sortie rates on unproductive "air occupation" missions.

Endurance as a UCAV requirement can be solved in many ways. Advances in engine technology will allow for more fuel efficient systems. As stated in a previous chapter, UCAVs can be designed to loiter at fuel efficient altitudes and descend to lower altitude to employ weapons. UCAVs can be fitted with jettisonable fuel tanks. The characteristic of endurance will again invalidate the use of most existing manned aircraft to be modified as UCAV candidates. Most modern tactical fighters simply do not have the un-refueled range to make them practical for unmanned weapons employment.

Beyond endurance, additional performance parameters need to be addressed. A high G, of at least 9 Gs, maneuvering capability is considered essential for manned tactical fighters. For a UCAV, 10 Gs would be a reasonable design limit. If defensive missile detection capabilities were built into the system, an expensive (in terms construction and performance tradeoff) high G capability would be unnecessary. A stealthy radar and infrared signature would generally limit missile attacks to fleeting shots outside optimum threat parameters. A defensive maneuvering capability combined with appropriate countermeasures would provide a high level of protection.

Design airspeeds can be kept subsonic, with higher subsonic speeds required only when necessitated by weapons employment. For an offensive counter air mission, supersonic airspeeds would only needed for brief periods during actual engagements.

The performance capability of a UCAV requires much study. All specific performance capabilities will be a compromise to the total mission requirements. Competing design specifications should be tailored to meeting the end goal of the UCAV's survivability and weapons employment.

4 Sensor and Weapons Configuration

Essentially this characteristic deals with payloads. Payloads not only means the more obvious package the vehicle carries to employ weapons, but entails subtleties as making space for sensors, antennas, weapons and weapons employment hardware. This characteristic is also crucial to the design concept of the vehicle. Once the UCAV concept is embraced, engineering priorities can then be based on mission effects capabilities which are not limited by pilot control functions and human life support. I see two basic avenues to follow.

The first is to use present weapons technology and available systems. In this case the UCAV could be outfitted with air-to-air missiles or laser guided bombs (LGB). A vehicle equipped with advanced medium range air-to-air (Amraam) missiles would have the advantage of a "launch and leave" capability. The UCAV system would receive targeting information based on data linked inputs from external sources such as airborne warning and control system (AWACS) or joint targeting and information distribution system (JTIDS). The operator would maneuver the UCAV into attack parameters and then fire the missile. The AMRAAM, following pre-programmed logic, acquires the target and then guides to a kill.

An LGB delivery would be based on the operator acquiring the target, and then commanding a launch. Terminal guidance for the weapon would be provided by the operator via real time data link control from the UCAVs on-board infrared sensors.

The advantages of using existing weapons systems include incorporating proven systems into the UCAV airframe. This strategy would also allow a system to be fielded more quickly as the primary design and engineering problem would be to mate the weapons system with the new airframe. However, I believe that following this path will severely restrict UCAV development and lacks the foresight needed to fully exploit the UCAV's true potential.

The second avenue (and the one I advocate) must be addressed with innovative technologies. Advances in weapons and sensor technology should allow for new capabilities to be mated with innovated concepts of UCAV potential. Advanced technologies such as side looking synthetic aperture radar (SAR) and hyper spectral sensors can provide a wide look capability for target identification. These systems can be miniaturized so as to be incorporated into the UCAV airframe without any design, performance or signature degregation.[11]

To achieve a balance of coverage in weapons delivery, the UCAV need not carry large conventional weapons. To fully exploit the true UCAV potential, advances in weapons technology must be incorporated. To fulfill the stealth characteristic requirement connotes the internal carriage of weapons. Internal weapons suggests limited weapon payload and complexity in the carriage and release system. Newly designed compact weapons will provide the answer to problems of limited payload capacity and complexity in the release systems.

There are many developing weapons technologies which can be exploited. As a result of the drive to develop conventional munitions that are smaller, it is necessary to increase the focus on the next generation seeker/sensor technology that will provide the accuracy for the smaller weapons to perform as well as current munitions.[12] The focus of this thrust is on the development of terminal seeker, sensor, processing, and guidance and navigation technologies for affordable autonomous weapons capable of all weather precision guidance.[13] The desired reduction in size requires a combination of improved precision guidance, enhanced energy/kill mechanism technologies and enhanced fuze control.[14] The hard target smart munition (HTSM), the smart soft target munition (SSTM), and the small smart bomb (SSB) are examples of the technology being investigated by the Armament Directorate at the Wright Laboratory at Wright-Patterson AFB. The concept of the small smart bomb is to produce a 250 pound class of precision munitions which will be capable of penetrating six feet of reinforced concrete.[15] The conventional penetrator in use by the USAF today is the BLU-109. The BLU-109 is a 2000 pound class weapon that is used as a free fall bomb or LGB component warhead. The 250 pound SSB system will be capable of servicing up to 85 percent of the current BLU-109 target set![16]

#5 Launch and Recovery

The current thought on how to launch and recover a UCAV is perhaps the best example of entrenched paradigms (to quote a phrase from the bygone quality movement).

Most advocates of a UCAV airframe have assumed the vehicles will take off and land like a normal manned airplane. Case in point is the configuration of the Predator, Tier II, and Dark Star vehicles. All use conventional launch and recovery methods with a form of retractable or fixed landing gear that have a requirement for a conventional runway. Fixed landing gear presents problems of drag and will be counterproductive in the environment of high threat due to the increase in radar signature. To build in a rugged and reliable landing gear system on a UCAV will cost in weight, performance, and design and development cost. The launch and recovery of unmanned target drones has proven to be THE single most hazardous aspect of a peacetime mission—a fault that can very easily migrate into UCAV operations. The operations of the QF-106 FSAT program serves to make that point painfully obvious.

Any UCAV that must takeoff and land on a conventional runway is a poorly conceived and inefficiently designed system. In a forward area it must rely on and compete for a runway that is necessary for manned aircraft and that will make it much more difficult to integrate into a total force package. No field commander that is engaged in combat operations would likely jeopardize his runway by allowing it to be used for the recovery of a UCAV. In fact there is probably no commander that is involved in any contingency operation (combat or otherwise) that will allow any type of unmanned vehicle to operate off his runway if there is ANY potential to damage that runway and render it unusable for manned operations.

I advocate simplicity and reliability in a design which will lead inevitability to cost effectiveness. Designers must look outside conventional manned aircraft operating requirements and develop alternatives to exploit the potential of the UCAV. There are several concepts that can be explored. Air launching UCAVs would offer tremendous benefits in endurance, secrecy in covert operations and increase the safety margin for the dangerous takeoff environment. However, UCAV size, weight or lack of suitable launch aircraft may prohibit an air launch design. A second and in some cases more practical option for launch would be to use a rocket assisted takeoff from a mobile launch rail. Benefits would include mobility, secrecy, and a wealth of experience based on proven and reliable systems already used on subscale target drones. A rocket assisted take off may enable a UCAV to be operated from extremely short taxiways or even blocked off roads and highways if operations off conventional runways does not prove suitable.

A rocket assisted launch of aircraft offers a proven history. Since the mid-1960s, there have been over 7,000 successful launches of BQM-34 and MQM-107 target drones from Tyndall Air Force Base in Florida. For the past three years alone, there have been a total of 572 subscale aerial target (SSAT) launches at Tyndall AFB[17]. Of those, only 3 were considered to be ops losses, and two of the three were in the launch and recovery phase. While the numbers are so low as to corrupt any statistical references, they do confirm the trend demonstrated by the QF-106 takeoff and landing accidents. They also contrast dramatically with the FSAT numbers for over all Ops Losses and verify the success of a specifically designed unmanned aircraft and refute the success potential of a modified manned fighter.

Recovery of the vehicle will be the second most hazardous phase of flight for a UCAV in peacetime operations second only to getting it safely airborne. To recover a UCAV, I advocate a simple and reliable alternative to a conventional landing on a manned-use runway. Again, simple and reliable equals efficiency and economy. A system designed to activate a motor cut off and a parachute land recovery system on command (or when preprogrammed requisite conditions are met) may prove to be the most reliable and effective method of recovering a UCAV. It will not interfere with any high priority runway operations and if well designed, the UCAV will incur minimal ground impact damage. Landing shocks can be mitigated by the use of inflatable air bags deployed underneath the aircraft just prior to impact. Minor damage can be absorbed and the vehicle will be able to be turned to the next sortie in minimal time. The current turn time for a SSAT at Tyndall is under three days if it has not received major damage by a missile impact. While SSAT operations are vastly different from that of an operational UCAV, there is a wealth of knowledge and experience which should be tapped in UCAV conceptual and operational design.

For operational missions a warhead would be installed in addition to the parachute system. Under hostile conditions, a UCAV operator will not allow any of his vehicles to be recovered in enemy territory. A UCAV would rather die than be captured! The controller would command an automatic destruct of the UCAV in the event the aircraft was not able to make it back to the recovery area. He would have several backups to insure the destruct command was received by the aircraft and the vehicle responded that it was going to destroy itself. A preprogrammed algorithm would be incorporated into the UCAV that would direct the auto destruct command if the autopilot met specific parameters of position, loss of command signal, or any critical control system malfunction. In the event that the UCAV landed in friendly territory, but outside the designated landing area, a system of safety interlocks will be incorporated so as to prevent the warhead from detonating near friendly troops or civilians of either side.

There are many other characteristics which must be considered to develop a true UCAV system capability. These are crucial to the success of the UCAV, but they do not necessarily dictate total airframe design.

#1 Airframe Control.

Perhaps the most critical issue pacing the evolution of UAVs is that of manual (human) versus automatic (computer) control of the wide range of functions to be executed during a mission.[18] The true UCAV will require a near autonomous control system, but the mission itself will be under the remote operator's total control. Human controllers have natural limitations such as the number of parameters that can be controlled simultaneously and the speed at which they can respond to changes. But they also have unique cognitive and reactive abilities that have not yet been replicated by automatic controllers.[19] The controller of a UCAV will then make all tactical and weapons employment decisions, but minimal actual "stick and rudder" flying control inputs.

#2 Control Signal

Any unmanned vehicle must operate on a secure control net to defend against jamming and signal intrusion. The signal complexity will depend on the amount of controller input to the vehicle and so to the degree of automaton available in the flight control autopilot. A high altitude ISAR UAV following a preprogrammed route and menu of instructions will naturally need a less intense control signal than a maneuvering UCAV employing weapons.

A beyond line-of-sight (LOS), two way communication system is mandatory. Mission signal requirements will be needed to provide control inputs to the UCAV autopilot for cruise, position data, video link for target acquisition and weapons employment, and threat signal interpretation. "To improve and increase reliability, all of these exchanges would most likely be broadcast over ultra high frequencies (UFH) and higher frequencies to provide high and low data rate transmissions. Data rate is defined as the number of equivalent binary digits transferred per second and is measure in bits per second (bps). Low data rate (LDR) is the ability to transmit and receive between 75-2400 bps. Medium data rate (MDR) is 2400 bps-1.544 Mega bits per second (Mbps) or 10 to the sixth power.[20]

The controller must have the capability to receive near real time performance feed back and employment video. The UCAV system must have the capability to receive near real time command instructions. That capability will be mandatory for selective targeting and weapons employment. Controller geographic position and signal relay capabilities will dictate the degree of autonomous control available for weapons employment. Real time control will require direct LOS from the vehicle to the controllers position or a signal relay via a satellite link. State of the art communications systems may allow the flexibility of either a forward deployed of centrally located controller.

Notes

[1] Martin, Paul, personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov, 1996, p. 33.

[2] Martin, Paul, personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov 1996, p. 33.

[3] Quote from Lt Col Dave Sandlin, USAF UAV Battle Lab, 53rd Wing, Eglin AFB, Fla, 1 Dec, 1997

[4] Martin, Paul, personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov 1996, p. 33.

Notes

[5] Martin, Paul, personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov, 1996, p. 11.

[6]. As per telephone interview of Lt Col Tony Stone, USAF ACC/DOU, 5 Feb, 1998.

[7] Martin, Paul, personal letter and Platform Panel report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov. 1996, p. 11.

[8] Based on records from the 82d Aerial Targets Squadron, 475 Weapons Evaluation group, Tyndall AFB, Fl.

[8] Based on records from the 82d Aerial Targets Squadron, 475 Weapons Evaluation group, Tyndall AFB, Fl

[9] Based on records from the 82d Aerial Targets Squadron, 475 Weapons Evaluation group, Tyndall AFB, Fl.

[10] Based on records from the 82d Aerial Targets Squadron, 475 Weapons Evaluation group, Tyndall AFB, Fl.

[11] [10] Maj Steve Bishop, USAF UAV Battle Lab, 53rd Wing, Eglin AFB, Fl.

[12] United States Air Force Air Material Command, *Conventional Armament, Visions and Opportunities* (off the internet), Wright Laboratory, Wright-Patterson AFB, OH, 1997, p. 3.

[13] United States Air Force Air Material Command, *Conventional Armament, Visions and Opportunities* (off the internet), Wright Laboratory, Wright-Patterson AFB, OH, 1997, p. 4.

[14] United States Air Force Air Material Command, *Conventional Armament, Visions and Opportunities* (off the internet), Wright Laboratory, Wright-Patterson AFB, OH, 1997, p. 6.

[15] United States Air Force Air Material Command, *Conventional Armament, Visions and Opportunities* (off the internet), Wright Laboratory, Wright-Patterson AFB, OH, 1997, p. 6.

[16] United States Air Force Air Material Command, *Conventional Armament, Visions and Opportunities* (off the internet), Wright Laboratory, Wright-Patterson AFB, OH, 1997, p. 6.

[17] Based on records from the 82d Aerial Targets Squadron, 475 Weapons Evaluation group, Tyndall AFB, Fl.

[18] Worch, P, Report on UAV Technologies and Combat Ooperations, Dr Peter Wroch, United States Scientific Advisory Board, Washington DC, Nov, 1996, p. 4-3.

[19] Martin, Paul, Personal letter and Platform Panel Report from USAF Scientific Advisory Board, Paul Martin,, Lockheed Skunk Works, Palmdale CA, Nov, 1996, p. 23.

[20] Nichols M, UCAVs and Commercial Satellites: The missing link (A research paper), Mark Nichols, Lt Col USAF, Maxwell AFB Al, Dec, 1997, p. 6.

Chapter 5

Potential Missions

It is very important to understand that I am not advocating building a UCAV to simply replace the F-117, F-15 or F-16. An advanced UCAV capability must be viewed as a force enhancement capability to project airpower effects! It should NOT be viewed simply as a manned aircraft replacement. Overall mission capabilities must be based on the unique attributes of UCAVs to operate in the three environments of high threat, endurance, and political sensitivity to captured pilots. Not every capability that *can* be built into a UCAV *should* be built in one.[1] UCAVs should be designed to provide effects to service specific political objectives or to enable other mission requirements. That is, you don't need to attack everything with a UCAV--you only need to compliment other existing but less effective targeting capabilities. The UCAV mission should be tailored to service specific problems in an aerial campaign plan. The UCAV mission is to support USAF doctrine. It would be counterproductive to build a UCAV just so it can haul bombs--we can already do that. UCAV design requirements should capitalize on currently limited capabilities and effects. UCAVs don't need BIG bombs--targets that require large warheads can be serviced by existing and improving systems such as the F-117 and various cruise missiles. Developing UCAV system potential demands *smart* weaponeering.

Air Force Manual 1-1 defined currently accepted missions of the USAF and airpower in general. The Scientific Advisory Board examined this list of missions with the intent to define potential UCAV contribution to mission success. An abbreviated list of missions includes:

- *Counter Weapons of mass Destruction*
- *Theater Missile Defense—Ballistic/Cruise Missiles*
- *Fixed Target Attack*
- *Moving Target Attack*
- *Moving Target Attack*
- *Jamming*
- *Intelligence, Surveillance and Reconnaissance*
- *Communications and Navigation Support*
- *Air-to-Air*
- Strategic Attack
- Space Control
- Area Denial
- Combat Search and Rescue
- Refueling Tanker
- Humanitarian Assistance

The Board considered a number of factors in an attempt to determine the applicability of a UCAV in each mission. These included platform characteristics, degree of autonomy in vehicle/flight management, reliability and maintainability, airspace deconfliction procedures, deployment considerations, remote versus forward basing, weapons integration and employment and human factors.[2]

From the expanded list of roles, the board selected the first nine missions (shown in italics above) as being critical to Air force needs and being representative of the original 22 missions for purposes of UCAV technology considerations.[3] The board concluded that some UCAV concepts will best complement manned systems and should be considered supportive platforms, whereas others can evolve to accomplish pre-planned and dynamically tasked missions autonomously.[4]

Those nine specific missions can be accomplished using UCAV technology. However, UCAV missions should not be thought of in the traditional roles of manned fighters such as suppression of enemy air defenses, fixed or moving target attack. To do so is to put a boundary on their development and hence employment capabilities. UCAVs must be thought of as enhancing the capability of round the clock coverage to achieve strategic results. Specific thought to UCAV development should be given to the missions of Strategic Attack, Special Operations and Area Denial. UCAV roles must not be bounded by specific weapons or traditional manned aircraft roles. With the proper application of UCAV technology, the terms "Air Campaign", "Air Occupation" and "Parallel Attack" can be refined by applying persistence and economy of effort.

Notes

[1] USAF UAV Battle Lab, 53rd Wing, Eglin AFB, Fl, Dec 1997

[2] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p 3-1.

[3] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p 3-1.

[4] Worch, P, Report on UAV technologies and combat operations (Vol I), Dr Peter Worch, United States Scientific Advisory Board, Washington DC, Nov 1996, p 3-1.

Chapter 6

UCAV Doctrine

Airpower today contributes directly to achieving the ultimate goal of full-spectrum dominance. The challenge is to continue to evolve our capabilities and doctrine to ensure that air and space power remains relevant to emerging threats and opportunities.

--Air Force Doctrine Document 1

Throughout this paper, I have stressed the need for advances in conceptual thinking as well technological capability. To effectively develop a viable UCAV, current advances in airframe, weapon, computer and human control systems must be mated together. This is also true in developing UCAV doctrine. I believe that there is a misconception about UAV concept of operations in general and there has been a movement towards developing a specific USAF doctrine for unmanned aircraft-armed or otherwise. In actuality, it would be counterproductive to attempt to develop a separate UCAV doctrine. The basic UCAV doctrine is already expressed in the *Air Force Doctrine Document 1*. Methods of UCAV (as well as UAV) tactical employment should be addressed *in Air Force Tactics, techniques and Procedures* (AFTTP) manuals just as in conventional manned aircraft. UCAV potential should be developed with the sole requirement of supporting published USAF doctrine not to support a tactical mission.

Operating in a high threat arena with the capability of endurance and without a risk posed to a pilot, a UCAV is uniquely capable of adding to the synergy that airpower brings to the modern battlefield. However, UCAVs will provide tremendous advancement in the offensive capability of airpower well beyond the actual battlefield. That capability can be tailored to meet the demands of a major regional conflict or a limited involvement in a quasi-military operation or stability and support operations.[1] A persistent UCAV with precision strike capability can strike directly at the strategic objectives of an air campaign with even less of a need for extensive tactical preparation by the most advanced conventional manned aircraft. As stated before, planners will not be hindered by the political considerations of a captured pilot or the ramifications of a potential rescue attempt. Planning will be based strictly on the strategic impact desired of an airstrike. Then the principle of the objective shapes priorities to allow air planners to concentrate on theater or campaign priorities and seek to avoid siphoning of force elements to fragmented objectives.[2]

The UCAV potential needs to be viewed as a natural extension of the basic tenants of airpower as described in Air Force basic doctrine[3]:

- Requires centralized control and decentralized execution
- Is flexible and versatile
- Produces synergistic effects
- Uniquely suited to persistent operations
- Operations must achieve concentration of purpose
- Operations must be prioritized
- Operations must be balanced

As such, all UAV and UCAV operations will be brought under the umbrella of the Joint Force Air Component Commander (JFACC). Airpower in general, and so UCAVs specifically, must be properly controlled so as to maintain the broad strategic and/or theater perspective in prioritizing the use of limited airframe assets to attain the objectives of all US forces in any contingency across the range of operations[4].

While centralized JFACC control will allow for proper offensive use of the UCAV capability, the unique characteristic of a detached remote control operator will offer unparalleled advantages in mission execution. The air component commander will now have direct access to target acquisition and mission information. In extremely sensitive political situations, this will allow for levels of control never seen before in the application of airpower. UCAV potential is in no way intended to detract from the concept of centralized control and de-centralized execution. But when the situation dictates, oversight of the UCAV at the highest level can be provided for target selection and Rules of Engagement compliance. This will in turn present air component commanders new and tremendous flexibility in the delegation and control of airpower assets and priorities.

Notes

[1] United States Army, *United States Army Manual 100-5, Basic Army Doctrine*

[2] United Stated Air Force, *AF Doctrinal Document-1, Air Force Basic Doctrine*, p. 13.

[3] United Stated Air Force, *AF Doctrinal Document-1, Air Force Basic Doctrine*, p. 22.

[4] United Stated Air Force, *AF Doctrinal Document-1 Air Force Basic Doctrine*, p. 23.

Chapter 7

ACQUISITION STRATEGY

In order to fully exploit the potential of UAVs, the Air Force must think of them as new and complete systems with new combinations of advantages and disadvantages, rather than as vehicles with a single outstanding characteristic or as a slight variant of an existing vehicle.

-USAF Scientific Advisory Board

The cornerstone of a UCAV capability will be the current Tier III Darkstar UAV. It is essential to proceed with the Dark Star as currently defined.[1] That will provide the building block experiences to begin conceptual design of a combat UAV. Credible aviation industry sources also advocate a “walk before you run” approach to UCAV development. While senior USAF commanders are strongly advocating the development of UAVs in general, UCAV development will present many risks.

Budget considerations will be a primary driver in developing a UCAV capability. In essence, UCAVs should not be viewed as simply a replacement airframe without a pilot on board. Development of UCAVs will not offer an inexpensive alternative to manned aircraft. UCAV aircraft will be expensive to design, develop, and build. However, the investment in a UCAV system is not towards single airframes, but must be structured towards a capability. UCAV concepts of system design and employment will offer many advantages and avenues towards cost savings in areas of development, design, test programs and manufacture.

An area of tremendous savings potential (when compared to manned operations) will be in operations and maintenance. As an example, one breakthrough concept of UCAVs is that the airframe should stay in controlled storage until needed for employment. That practice will offer tremendous benefits to the operational requirements and maintenance of airframes. Except for infrequent systems verification flights, UCAV airframes need only be flown for actual mission requirements. Routine training and mission dress rehearsals will be conducted in the simulator. Realistic simulations of the actual target area will provide an invaluable first-look to the controller. Specific tactics and weapons employment can be rehearsed prior to the actual mission which will dramatically improve mission success. The major cost of providing a fleet of flying aircraft to support peacetime training requirements will vanish. This will also mitigate the problem of operational losses of aircraft in training flights. That in turn, will allow the system as a whole to absorb a higher loss rate under combat conditions and still retain a viable capability.

One designated squadron will become responsible for the storage and maintenance of "boxed" UCAV aircraft. They would also be responsible for a large simulator program for controllers and the minimal active flying training. To integrate the system into general Air Force operations, training could be conducted that would involve participation in actual manned flying excursuses. Prior to any operational deployment, designated UCAV airframes will be flown on a functional check flight profile to ensure systems operations and control interface. These flights will be strictly controlled to maintain a high degree of readiness in the stored fleet.

Planned limited aircraft life should also be a design factor. While not intended to be a “throw away after one use” asset, a UCAV need not be built to tolerances expected of manned aircraft that will fly many thousands of flights over their operational life which may be measured in decades. It is difficult to estimate exactly how many operational flights a UCAV will average in it’s life time. On one side of the extreme, during the Viet Nam war, an ISAR BQM-34 flew almost 70 missions over heavily defended targets in North Viet Nam before it was brought down by anti-aircraft fire[2]. On the more realistic side--the life expectancy of a BQM-34 and MQM-107 averages just over 8 flights per airframe at Tyndall AFB before it is destroyed[3]. The QF-106 averaged just over 5 missions per aircraft over the life of the system.[4] That is a mean average based on all factors including live fire missile shots against it and included countermeasures such as wingtip flare pods and electronic jamming.

Airframes must be designed to afford simplicity in maintenance. Traditional concepts of maintainability and supportability will have to be addressed early in the design process. The simple concept of conveniently placed maintenance access panels must be a high operational priority.[5] Funding practicalities will not allow a design change to improve production models over demonstration/test airframes, so operational considerations MUST be incorporated into the initial design. Test airframes MUST be designed to represent operational maintainability. This will obviously necessitate a high up-front unit cost and development effort. However, it will ensure a high systems reliability and life time maintainability and is mandatory to controlling the mean-time-between-failure rates of the various systems.

It should be again stressed that UCAVs must not be considered as representative of a one-for-one trade off with manned aircraft. UCAVs must be viewed as representing a capability and the systems must be maintained and operated in the most efficient manner possible. Any cost reductions in maintainability and supportability will be magnified in an unacceptable ops loss rate as the system matures. A UCAV must fly correctly the first time-every time. In the Predator UAV system, a current total of 17 aircraft remain after a loss of six aircraft. Two aircraft were lost in developmental flights and four during operational flights. Of the operational losses, only one was due to combat fire. Three aircraft were lost due to engine failures. Each of these failures occurred in-flight after an extremely long mission as the aircraft was returning to base.[6]

For the system to become and remain viable, the Air Force must move UCAV development into the mainstream of acquisition and logistics procedures.[7] The present family of ISAR UAVs seem to be stuck in a logistical and operational limbo—that is, advanced concept and technology demonstrators are essentially put into the operational world without due consideration to support and maintenance requirements.

An operational UCAV must also be developed so as to be workable in the level and type of logistical support represented by current manned systems. Military versus civilian contractor maintenance and local versus depot level logistical support will depend on the size of fleet and the general deployment requirements. A support network must be included in the acquisition process. That support "train" must be designed to follow the UCAV airframe and control systems to forward deployed operating locations. Standard supply and maintenance Technical Order publications are mandatory. The lack of proper supply and maintenance procedures will dramatically affect the mission capability and the operational loss rate of any aircraft. That same lack of attention in UCAV development will be a show stopper. It must be addressed and FUNDED in the development and acquisition phase. Based on the FSAT experience at Tyndall AFB, it is not an overly simplistic concept to stress again that there is no man inside to take corrective action during malfunctions.

Notes

[1] Martin, Paul, Personal letter and Platform Panel Report from USAF Scientific Advisory Board, Paul Martin, Lockheed Martin Skunk Works, Palmdale, CA, Nov 1996, p. 23.

[2] McGoingle, Ronald L, Unmanned Aerial Vehicles (UAVs) on the Future Tactical battlefield—Are UAVs an Essential Joint Force Multiplier?, Ronald L. McGoingle, USAF Air Command and Staff College, Maxwell AFB, Al, Dec 1992, p 5.

[3] Based on records from the 82 ATRS, 475 WEG, Tyndall AFB. Note: The life-time record holder for a SSAT at Tyndall AFB is 24 missions.

[4] Based on records from the 82 ATRS, 475 WEG, Tyndall AFB. Note: The life-time QF-106 record holder for unmanned missions is 15.

[5] USAF UAV Battle Lab, Lt Col Tom Toeltzien, 53rd Wing, Eglin AFB, FL, 1 Dec 1997.

[6] Per telephone interview with Lt Col Tony Stone, USAF ACC/DOU, Langley AFB, VA, 5 Feb 1998.

[7] USAF Battle Lab, 53rd Wing, Eglin AFB, FL, 1 Dec 1997

Chapter 8

Conclusions

The full range of benefits available from physically removing the human operator from the aircraft includes much more than the mere (5-10%) reduction in weight achievable from elimination of the crew.

-Lockheed Martin Skunk Works

The UASF is at the cross roads for UCAV development. The USAF must decide how to proceed with developing mission capability and how it supports its doctrine.

It will be a dramatic **evolution** if UCAVs are developed with the mindset of developing a platform to haul conventional weapons without a pilot onboard. That concept would involve automating an F-4 or F-16 to send to Bosnia, or putting LGBs on Predator or Tier II Plus type airframes to act as replacements to the manned A-10 or F-16. It would also demonstrate a myopic vision and not fully capitalize the true potential of airpower.

It will be a **revolution** if UCAVs are developed with the concept to exploit technology to make a quantum jump to dramatically expand air power's potential. Air Force leaders must take the bold step to take air power beyond the precision weapons and stealth breakthroughs of the past decade. A UCAV is a natural extension of those breakthroughs that will provide air planners new capabilities in planning, control and execution of airpower as a method of force employment. It has been said that the future Joint Strike Fighter will be the last manned operational fighter for the USAF, but a

UCAV should in no way affect the requirement for manner fighter and bomber platforms.[1]

Clearly, a UCAVs will best serve as a **compliment** to manned systems. Some UAVs should be considered supportive platforms, whereas UCAVs can evolve to accomplish pre-planned and dynamically tasked missions autonomously.[2] However, when the situation dictates operations in the high threat, extreme endurance or politically sensitive environments, UCAVs will present theater commanders and the national command authority the best force projection method. In extreme cases a UCAV may present commanders with their only viable employment vehicle. That in itself, is the most pressing argument to justify a revolution in airpower capability.

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Notes

[1] Briefing at the USAF Air War College, Maxwell AFB, AL, 3 Feb, 1998.

[2] Worch, P, Report on UAV technologies and combat operations,(Vol I) United States Air Force Scientific Advisory Board, Washington DC, Nov 1996, p3-1.

Glossary

AGL Above ground level

Amraam Advanced medium range air-to-air missile

ISAR Intelligence, Surveillance and reconnaissance

FSAT. Full Scale Aerial Target In this paper refers to the QF-106 and QF-4 drone aircraft operated by the USAF on the Gulf and White Sands Missile Ranges. Both aircraft are modified retired fighters that are specially fitted with the necessary autopilot and control functions that allow it to be flown by remote control

Operational Loss (Ops Loss) Refers to the loss of a aircraft (specifically a drone or UCAV) that is lost for any other reason than a missile of hostile shootdown. For instance, human error, any airframe component of software failure that resulted in the loss of an aircraft would be an Ops loss.

RAM Radar absorbent material. In this context, a special material applied to the outer skin of an aircraft designed to reduce the amount of radar energy reflected off the aircraft.

RCS Radar Cross Section

SSAT. Subscale Aerial Target. In this paper refers to the MQM-107 and BQM-34 unmanned drones used for live weapons testing by the USAF on the Gulf and White Sands Weapons Ranges

TACD Tactical advanced decoy. A concept and system not addressed in this paper

82 ATRS The 82d Aerial Targets Squadron, based at Tyndall AFB and part of the 475 Weapons Evaluations Group. The sole unit in the USAF responsible for operating and maintaining full scale (QF-106 and QF-4) and subscale (BQM-34 and MQM-107) aerial targets for use in live fire weapons test and evaluations on the Gulf and White Sands Missile Ranges.

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